OPEN ARTERIAL REVASCULARIZATION OF THE CRITICALLY ISCHEMIC FOOT USING ARTERIAL HOMOGRAFT

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ABSTRACT • BACKGROUND : Revascularization alternatives for patients with critical limb ischemia and without adequate autogenous vein remain challenging. We reviewed our experience with the use of arterial homograft as a conduit for limb salvage in patients with limb ischemia and active lower extremity infections.

METHODS : A retrospective review of patients who underwent open arterial revascularization of the lower extremity with cryopreserved femoral artery homograft for the treatment of symptomatic critical limb ischemia (i.e., foot ulceration, infection, or gangrene) during an 18-month period was performed. Relevant clinical variables and treatment outcomes were analyzed. Clinical success was defined as limb salvage for one year, patency of the reconstruction, and wound healing.

RESULTS : Thirteen patients (5 men; average age 71 ± 8.3 years, range 51-87 years) were treated during this study period. Treatment indications included 10 (77%) foot ulcerations, 2 (15%) critically ischemic limbs without ulceration, and 1 (8%) infected polytetrafluoroethylene bypass graft with acute occlusion and limb ischemia. A femoral below-the-knee popliteal bypass was performed in 4 (1%), femoral to anterior tibial artery in 4 (31%), femoral to posterior tibial artery in 3 (23%), and femoral to peroneal artery in 2 (15%). All 13 limbs were preserved. Minor amputations were performed in 6 patients, 2 underwent toe amputations and 4 patients had a trans-metatarsal amputation. The cumulative patency rate at 6, 9, and 18 months was 92.3%, 70.3%, and 58.6%, respectively.

CONCLUSION : Open arterial revascularization with arterial femoral homograft is an acceptable treatment method in patients with critical limb ischemia and active infection in whom autogenous vein is not available or the use of a synthetic conduit is not possible.

Keywords : vascular, arterial homograft. peripheral bypass, limb ischemia

RÉSUMÉ • CONTEXTE : Les alternatives de revascularisation pour les patients se présentant avec une ischémie critique des membres inférieurs et n'ayant pas de veine autogène adéquate restent difficiles. Nous avons examiné notre expérience avec l'utilisation de l'homogreffe artérielle comme un conduit pour le sauvetage du membre chez les patients souffrant d'une ischémie critique ou d'une infection active du membre inférieur.

MÉTHODES : Une étude rétrospective des patients ayant subi une revascularisation artérielle de l'extrémité inférieure avec une homogreffe de l'artère fémorale cryoconservée pour le traitement de l'ischémie critique symptomatique des membres (c.-à-d., ulcération, infection ou gangrène du pied) pendant une période de 18 mois a été effectuée. Les variables cliniques et les résultats du traitement ont été analysés. Le succès clinique était défini comme suit : sauvetage du membre, perméabilité de la reconstruction, et cicatrisation des plaies après un an.

RÉSULTATS : Treize patients dont 5 hommes, âgés de 51 à 87 ans, âge moyen : 71 ± 8,3 ans, ont été traités au cours de cette période. Dix patients avaient des ulcérations au pied (77%), 2 (15%) des ischémies critiques du membre sans ulcération, et 1 (8%) avait un pontage en polytétrafluoroéthylène infecté avec une occlusion aiguë et ischémie du membre. Un pontage fémoro-poplité sous-articulaire a été effectué sur 4 patients (1%), un pontage fémoro-tibial antérieur sur 4 (31%), un pontage fémoro-tibial postérieur sur 3 (23%) et un pontage fémoro-péronier sur 2 (15%). Tous les membres des 13 patients ont été préservés. Des amputations mineures ont été réalisées chez 6 patients : 2 ont subi une amputation de l'orteil et 4 une amputation trans-métatarsienne. Les taux de perméabilité cumulatifs à 6, 9 et 18 mois étaient de 92,3%, 70,3% et 58,6%, respectivement.

CONCLUSION : La revascularisation artérielle ouverte par homogreffe artérielle fémorale est un traitement acceptable chez les patients présentant une ischémie critique ou une infection active des membres inférieurs quand une veine autogène n'est pas disponible ou que l'utilisation d'un conduit synthétique n'est pas possible.

Mots-clés : vasculaire, homogreffe artérielle, pontage périphérique, ischémie des membres

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INTRODUCTION

Patients with critical limb ischemia (CLI) may develop toe or foot ulceration, necrosis, or gangrene which can occur either as a result of disease progression or following trauma or surgery to a limb affected by poor circulation. In general, most patients with CLI and tissue involvement progress to amputation, thus highlighting the importance of prompt therapy and revascularization. Autogenous vein should be used when available for infrainguinal bypass. When autogenous vein is not available, other conduit options should be considered, such as polytetrafluoroethylene (PTFE) or Dacron grafts, or other non autogenous conduits such as human umbilical vein, cryopreserved arterial (CAA) and venous (CVA) allografts. The latter are especially useful in patients with CLI without available autogenous vein, and especially in the face of systemic or localized infection in which the use of synthetic materials is contraindicated [1]. Revascularization alternatives for patients without adequate autogenous vein and with CLI can be challenging. We reviewed our experience with the use of arterial homograft as a conduit for limb salvage in this particular group of challenging cases.

METHODS

We reviewed the clinical data of 13 patients who underwent open arterial revascularization of the lower extremity with cryopreserved femoral artery allograft (CryoLife, Inc., Kennesaw, GA) for the treatment of symptomatic critical limb ischemia that included foot ulceration, infection, or gangrene during an 18-month period at The Methodist Hospital in Houston, Texas. Relevant clinical variables and treatment outcomes were analyzed. Clinical success was defined as limb salvage for one year, cumulative patency of the reconstruction, and wound healing. Study data was obtained via a review of the patient's medical records as part of an Institutional Review Board approved protocol.

Allograft preparation

The allograft thawing and rinsing procedure was performed according to the package insert protocol. Briefly, the Cryosafe pouch was allowed to thaw at room temperature for 3 minutes and then placed in a basin containing 3 liters of normal saline at a temperature between 37 °C and 42 °C. Once the contents thawed, the outer pouch was carefully opened to retrieve the sterile pouch containing the allograft. This second inner pouch was opened and the allograft (along with the solution) was poured into a sterile basin. It is important at this step to remove the end caps from the flow ports or cannulas to avoid over-pressurizing the conduit during rinsing. A series of 5-minute preparations then followed. Rinsing solutions are provided with each allograft. The allograft was gently perfused with approximately 50 to 60 mL of solution A and allowed to remain in solution to balance for 5 minutes. The same step was repeated using solution AB, followed

TABLE I
RISK FACTORS and COMORBIDITIES

COMORBIDITIES	Patients	
	N	%
HTN	10	83.3
DM	7	58.3
CAD	10	83.3
COPD	2	16.6
PVD	12	100.0
Previous bypass	4	33.3
CRI	2	16.6
ESRD	4	33.3
Hyperlipidemia	4	33.3
Tobacco use	5	41.6

HTN: hypertension   **DM**: diabetes mellitus   **CAD**: coronary artery disease   **COPD**: chronic obstructive pulmonary disease   **PVD**: peripheral vascular disease   **CRI**: chronic renal insufficiency   **ESRD**: end-stage renal disease

by solution B. The allograft was then left in solution B until time of use. The allograft was flushed with heparinized (5000 U heparin/500 mL) lactated Ringer's solution and carefully inspected for leaks. Any repairs were carried out using 7-0 Prolene® (Ethicon, USA) suture. The segments in contact with the cannulas at both ends were excised. If it was necessary to splice two allografts together, running 6-0 Prolene® suture was used in an end-to-end fashion.

Implantation technique

We performed the proximal anastomosis using 5-0 or 6-0 Prolene® in an end-to-side fashion. The graft was arterialized. We believe this step is important because the arterialized graft increases in length compared to its non-pressurized state. We prefer to tunnel the allograft in a non-anatomical position and above the fascia deep within the subcutaneous fat. If the distal target is below the knee, an additional small incision was made above the level of the knee to ensure and aid proper tunneling. We used an 8 mm GORE tunneler (W.L. Gore and Associates, Inc., Flagstaff, AZ). The tunneler was advanced retrograde towards the arterialized allograft. A 2-0 silk tie was secured onto the distal end of the graft to keep it pressurized and to pull the graft through the tunneler. This maneuver prevents the pressurized conduit from twisting

TABLE II
INDICATIONS for TREATMENT

INDICATIONS	Patients	
	N	%
Infected bypass (PTFE)	1	7.7
Foot wound or Gangrene	10	76.9
Foot ischemia (no wound or gangrene)	2	15.4

PTFE: polytetrafluoroethylene

TABLE III
TYPE of BYPASS PROCEDURE PERFORMED

BYPASS PROCEDURE	Patients N	%
Femoral - (BK) popliteal	4	31
Femoral - Anterior tibial	4	31
Femoral - Posterior tibial	3	23
Femoral - Peroneal	2	15

BK: below knee

TABLE IV
MINOR PROCEDURES and AMPUTATIONS

TREATMENT AFTER BYPASS	Patients N	%
None	5	38.5
Wound care or Debridement	2	15.4
Toe amputation	2	15.4
TMA	4	30.8

TMA: trans-metatarsal amputation

or kinking during tunneling. The allograft was tunneled to the mid-incision and then tunneling was continued to the distal anastomotic region. With the graft arterialized, the area for the anastomosis was marked and the allograft divided to proper length. The allograft was clamped with a bulldog clamp at the proximal edge of the distal skin incision. This is important because once the graft is de-pressurized, it will retract into the tunnel tract when freed of arterial pressure. This maneuver also prevents over-sizing of the length of the bypass conduit.

A completion on-table arteriogram was performed to evaluate the bypass upon finalizing the anastomoses. Patients were kept on appropriate antibiotics, 81 mg of aspirin daily and Plavix (Bristol-Myers Squibb/Sanofi Pharmaceuticals, Bridgewater, NJ) at 75 mg daily following surgery.

RESULTS

Thirteen patients (5 men; average age 71 ± 8.3 years, range 51-87 years) were treated during this study period. Their risk factors and comorbidities are listed in Table I. Treatment indications included 10 (77%) foot ulcerations, 2 (15%) critically ischemic limbs without ulceration, and 1 (8%) infected polytetrafluoroethylene bypass graft with acute occlusion and limb ischemia (Table II). All patients underwent vein mapping to assess the size and potential use of a venous conduit and these patients were determined not to have an adequate greater saphenous vein or upper extremity vein suitable for use as a bypass conduit. Patients on dialysis did not have their
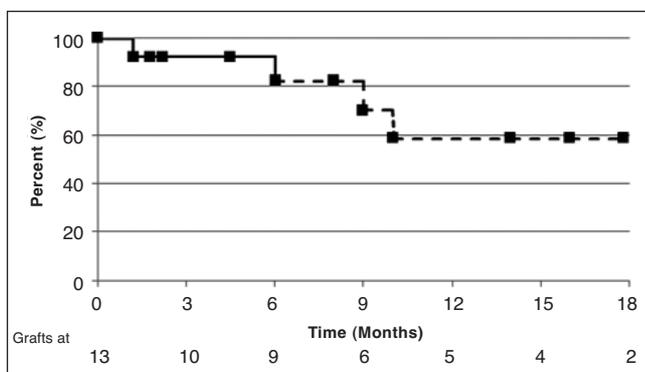

FIGURE 1. Cumulative patency rate by Kaplan-Meier analysis

Grafts at: 13 (0), 10 (3), 9 (6), 6 (9), 5 (12), 4 (15), 2 (18)

upper extremities mapped. A femoral to below-the-knee popliteal bypass was performed in 4 patients (31%), femoral to anterior tibial artery in 4 (31%), femoral to posterior tibial artery in 3 (23%), and femoral to peroneal artery in 2 (15%) (Table III). Minor amputations were performed in 6 patients; 2 underwent toe amputations and 4 patients had a trans-metatarsal amputation (Table IV). No major amputations were performed during the 18-month follow-up period. Assisted patency was achieved in two patients. The first patient required percutaneous transluminal balloon angioplasty (PTA) of a mid-allograft stenosis. The second patient required PTA of a proximal and distal anastomotic stenosis. One patient, who was confirmed to be hypercoagulable, failed to comply with the warfarin anticoagulation regimen and underwent percutaneous thrombolysis after graft thrombosis. The cumulative patency rate by Kaplan-Meier analysis [2] at 6, 9, and 18 months was 92.3%, 70.3%, and 58.6%, respectively (Figure 1).

DISCUSSION

Patients with CLI will present with symptoms that can vary from a lack of a pulse or Doppler signals in the affected limb, motor or sensory dysfunction, skin temperature or color changes, rest pain, ulceration, and even gangrene. Patient evaluation should begin with a detailed history and physical examination. If the limb is in immediate jeopardy, attempts at re-intervention should be undertaken. In fact, numerous reports have demonstrated that patients can benefit from repeat revascularization or limb-preserving interventions even after failed arterial reconstructions [3-5]. Computed tomography angiography (CTA) or magnetic resonance angiography (MRA) can be used to delineate or map the vascular anatomy and help therapeutic planning. However, the latter can overestimate the extent of disease, especially when flow is severely compromised, hence failing to expose a potential open infra-popliteal target vessel. Digital subtraction angiography (DSA) is the gold standard for the evaluation of the ischemic or at-risk extremity. A complete exam should include an abdominal aortogram, imaging of the iliac or pelvic vessels, and serial images of the lower extremity including the foot and toes. Every effort should be made to clearly identify a target vessel and its runoff in preparation for an open surgical bypass. This will often require

additional injections of contrast dye and images focusing on the distal limb and potential runoff. This detailed angiographic search will often demonstrate a patent distal infrapopliteal vessel adequate for bypass. If uncertainty exists, at the time of surgery an open, on-table angiogram using a 21- 23 G angiocatheter placed into the target vessel can better help delineate the operative plan and extend operability [6].

Autogenous vein should be used when available for infrainguinal bypass and has characteristically been the most favored conduit for bypass. Harris and associates [7] used in situ greater saphenous vein (GSV) in 71 patients for limb salvage. The patency rate at one year was 80% when the anastomosis was done to the popliteal artery and 75% when done to an infrapopliteal vessel. Limb salvage at one year was 91%. In a study of 440 consecutive in situ GSV bypasses, Donaldson and colleagues [8] achieved a primary revised patency (revised while still functioning) of 78% and limb salvage of 88% at 5 years. Eighteen grafts were identified during surveillance and revised while still patent.

When autogenous vein is not available, the use of alternate conduit options should be considered; these include polytetrafluoroethylene (PTFE) or Dacron grafts, and other non-autogenous conduits such as human umbilical vein, CAA and CVA allografts. These conduits are useful in patients without available autogenous vein, particularly in cases of systemic or localized infection in which the use of synthetic materials is contraindicated [1,9]. Support for the use of CVA for bypass through infected fields in patients without an autogenous conduit comes from a study of 240 patients in whom limb salvage rates at 1 and 2 years were 80% and 71%, respectively [10]. In addition, Bannazadeh and associates evaluated their experience using CVAs for infrageniculate revascularization in 66 patients with a history of failed bypass or no suitable autogenous vein and reported a 73% limb salvage rate [11].

In a study by Desgranes and associates [12], CAA conduits were used for the treatment of infected vascular grafts. Treatment consisted of either total or partial removal of the pre-existing infected vascular graft. The authors concluded that CAA was useful in selected cases. However, the conduits were not totally resistant to infection. The authors suggest a close follow-up of patients to detect potential long-term alterations of the allografts. A more recent study evaluated the safety and efficacy of CAA in the management of major peripheral arterial graft infections. Seventeen patients underwent graft excision and CAA reconstruction. Two patients experienced allograft rupture at the groin within the early postoperative period. However, during the mean follow-up of 32 months there was no persistent or recurrent infection. The primary and secondary patency at 18 months was 68% and 86%, respectively [13].

Castier and colleagues [14] evaluated the use of CAA for below-the-knee revascularization for limb salvage in the absence of a suitable autogenous saphenous vein in 32 patients. Primary patency at 6, 12, and 18 months was 75%, 57%, and 39%, respectively. Secondary patency at 6, 12, and 18 months was 75%, 75%, and 59%, respectively. Limb salvage was achieved in 73% of patients at 18 months.

The non-anatomical graft position is a technique our group commonly uses. It provides for easier surveillance and potentially easier access for revision when necessary. There is limited experience with the use of arterial homograft and long-term medical strategies for maintaining graft patency. The long-term use of Aspirin and Plavix in this population of patients intends to modify the risk factors for atherosclerosis and simultaneously decrease the long-term risk of cardiac events and stroke that inevitably affects the patients with CLI. As such, our cumulative patency results are similar to those reports that have utilized CAA for lower extremity bypass. Minor procedures or amputations were necessary in 61.5% of patients. At the time of follow-up, those sites had healed, even in cases in which the bypass had already failed. However, longer follow-up is needed to determine the ultimate fate of the affected limb as well as patient mortality as it relates to their underlying comorbidities and disease.

In general, most patients with CLI and tissue involvement progress to amputation, thus highlighting the importance of prompt therapy and revascularization. Unfortunately, the mortality for patients presenting with CLI is approximately 50% to 70% at 5 years [15-16]. When an expeditious and appropriate evaluation is performed, this can lead to an increase in the revascularization rate and even a 50% reduction in the amputation rate [17-18]. However, a delay in treatment and referral of patients with CLI to a vascular surgeon can hinder limb preservation efforts and lead to amputation [19]. When amputation is performed, patients remain at risk for stump complications and even conversion to a higher level amputation. Patient mortality for below-the-knee (BKA) and above-the-knee (AKA) amputations at three years has been documented at 43% and 63%, respectively [20].

This study demonstrates our capacity to perform an infrainguinal bypass with CAA. A certain selection bias exists. Patients who were not deemed candidates for revascularization or limb salvage with a minor amputation or debridement procedure were likely not considered for intervention. In addition, over a third of the patients were on dialysis and at least half had diabetes. It would be valuable to assess the patency of CAA in a group without these concomitant risk factors. No doubt, controlled studies beyond these case series reports need to be implemented to ascertain if the patency associated with this costly implant reaches a favorable long-term outcome for patients.

As our elderly population grows, so will the number of patients with CLI who can benefit from limb-preserving procedures. Among those, there will be patients in whom the use of cryopreserved allografts may be the only alternative for bypass as opposed to amputation. Therefore, the impact of the health-related expenses, morbidity and mortality associated with these interventions needs to be addressed.

CONCLUSION

Open arterial revascularization with arterial femoral homograft is an acceptable treatment method for limb preservation in patients with critical limb ischemia, gangrene, or ulceration in whom autogenous vein is not available or the use of a synthetic conduit is not possible.

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